Detection of a Fine-scale Discontinuity of Photospheric Magnetic Fields Associated with Solar Coronal Loop Brightenings

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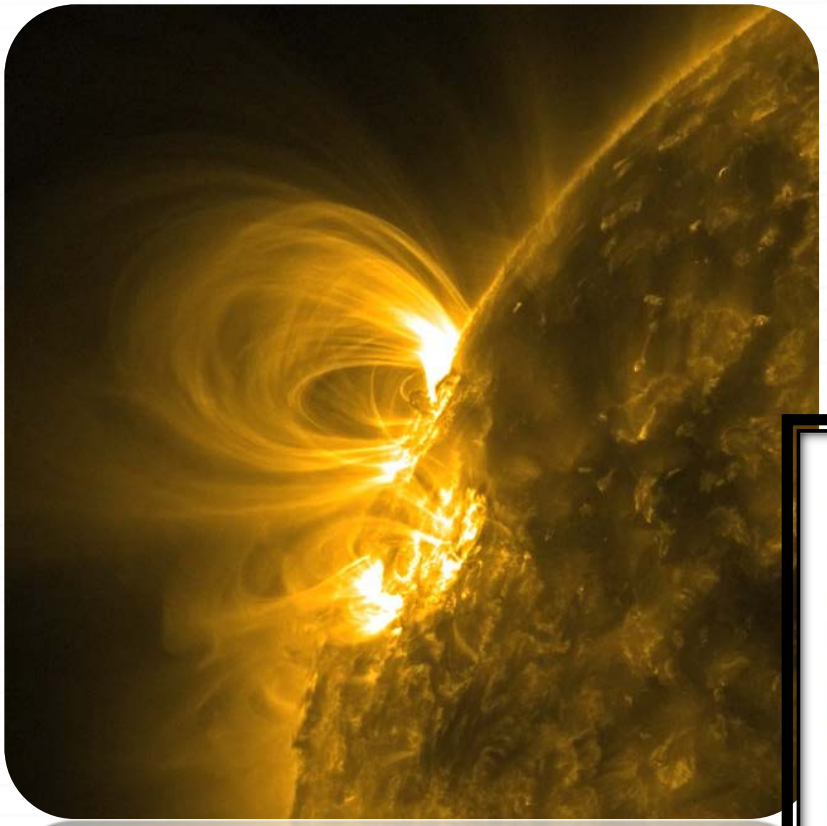
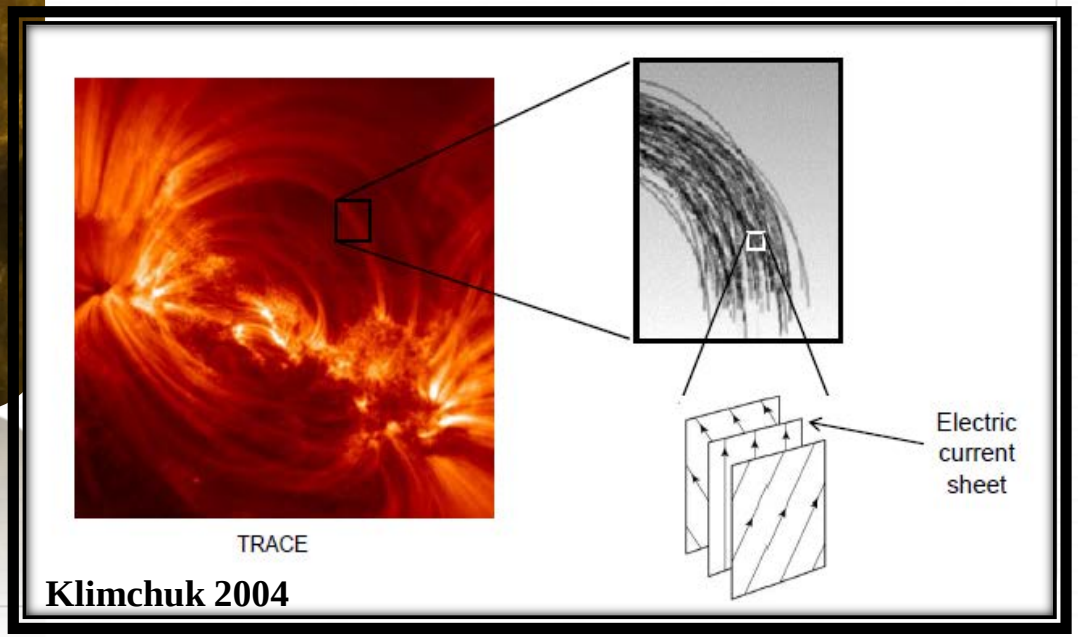
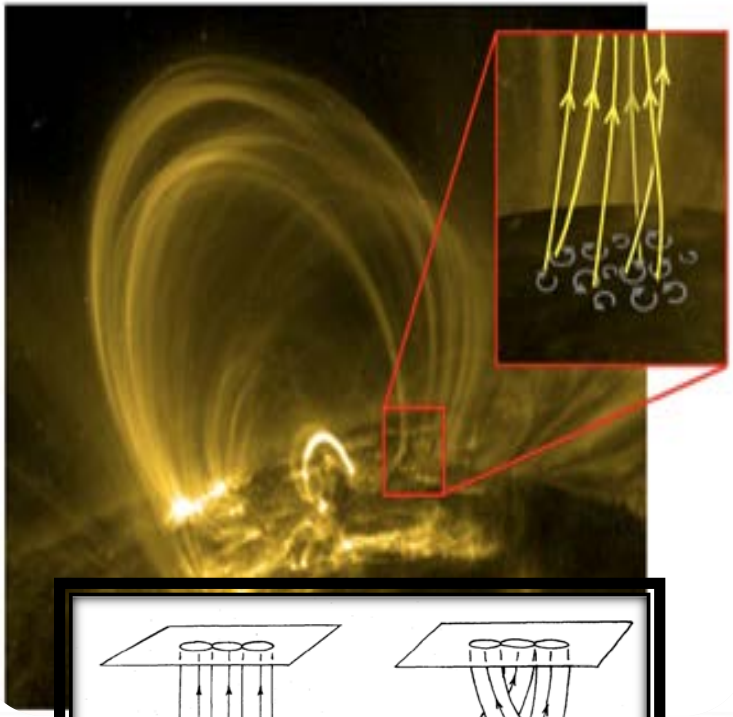
Introduction

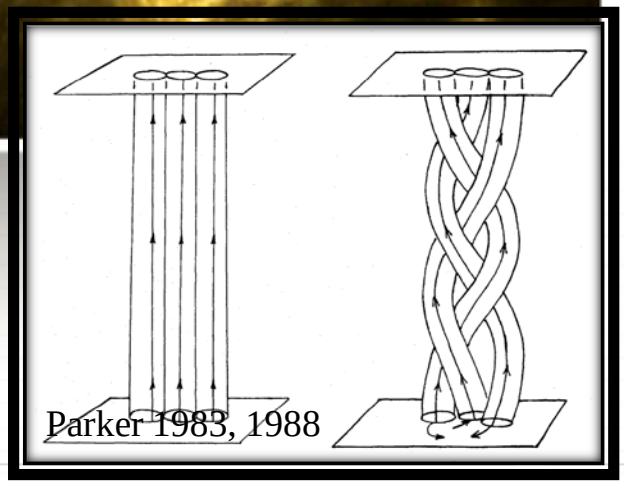


- **Bright coronal loops**
  - the indication of heating
- **Nanoflare theory** (Parker 1983, 1988)
  - a bundle of thin strands



Introduction





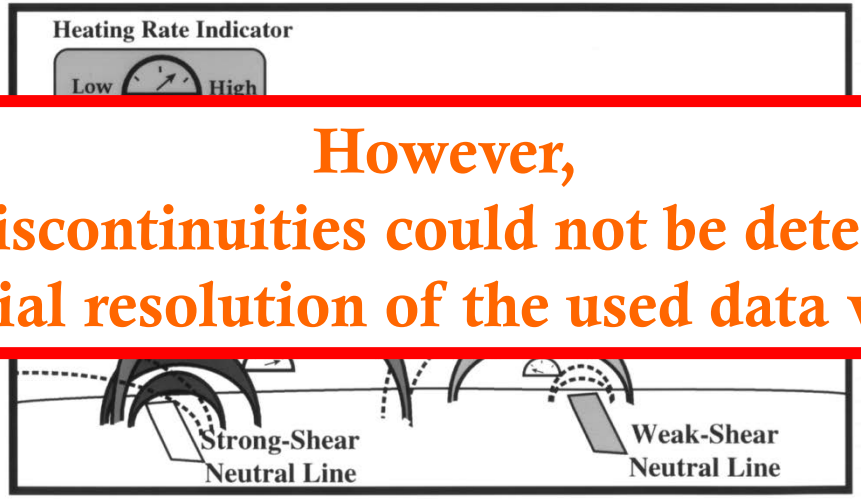
- **Bright coronal loops**
  - the indication of heating
  - a bundle of thin strands
- **Nanoflare theory** (Parker 1983, 1988)
  - a bundle of thin strands
  - braiding – random motion of photosphere
  - small-scale tangential magnetic field discontinuities

- ***However, the direct measurement of coronal magnetic fields at such fine-scales is not possible, currently.***

An alternative approach is to detect magnetic discontinuities in the photosphere where coronal loops are rooted.

Introduction

- **the photospheric magnetic origin of coronal heating (Falconer et al. 1997)**
  - most enhanced heating of coronal loops requires the presence of a polarity inversion line (PIL) in the magnetic field near at least one of the loop footpoints.
  - the magnetic reconnection triggered by the high non-potentiality at the loop footpoints is the prime process of the heating.
  - the loops can be filled with hot plasma evaporated from the footpoints like major flares (Reale et al. 2000a, 2000b)



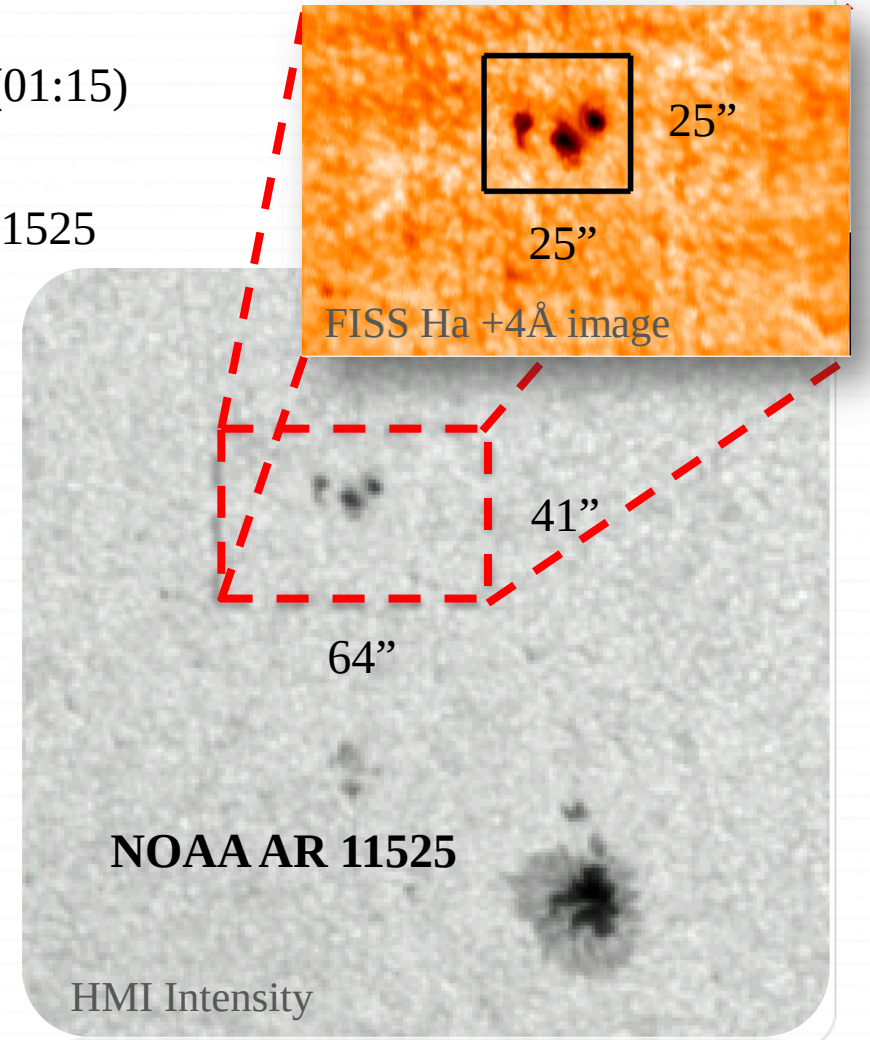
However,
magnetic discontinuities could not be detected because the spatial resolution of the used data was poor.

Motivation

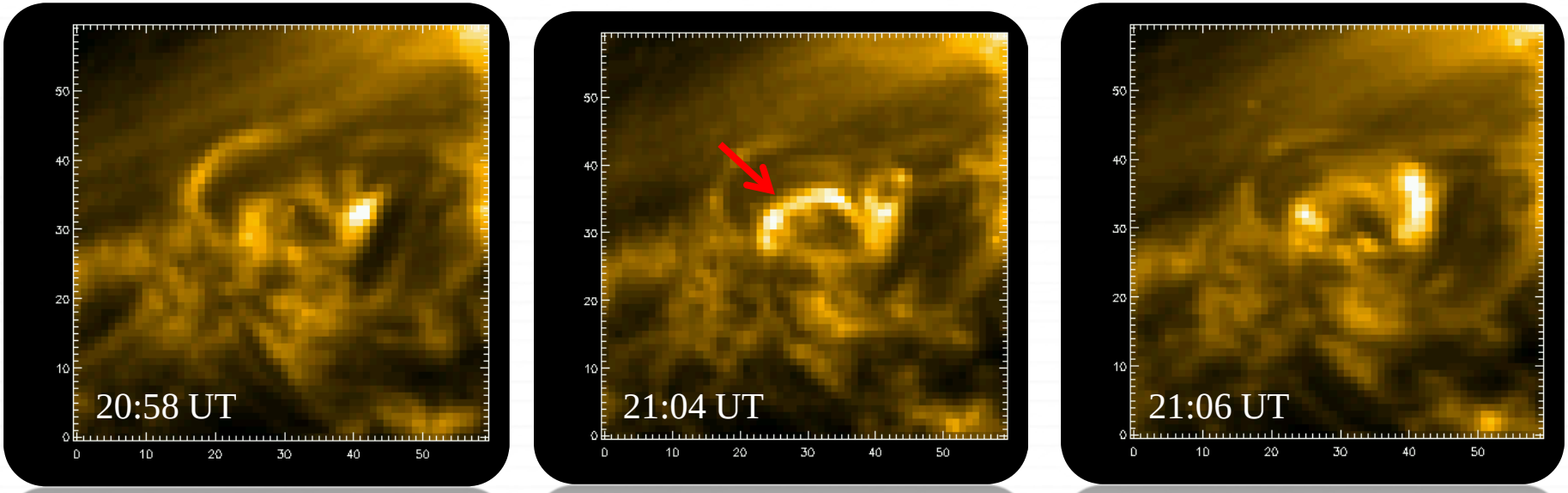
To detect a fine-scale magnetic discontinuity in the photosphere that is causally related to the events of coronal heating in a small coronal loop.

Observations

- **Date / Time** : 2012.07.19. / 20:26~21:41 UT (01:15)
- **Location** : north of the NOAA active region 11525
- **FOV / Cadence** : 64” x 41” / 63.5 sec
- **Instruments**
  - Fast Imaging Solar Spectrograph (FISS)
    - Hα & Ca II 8542Å bands
  - InfraRed Imaging Magnetograph (IRIM)
    - FeI 1.56 μm, spatial resolution ~ 0.2”
  - Solar Dynamic Observatory (SDO)
    - EUV bands, HMI intensity/magnetogram

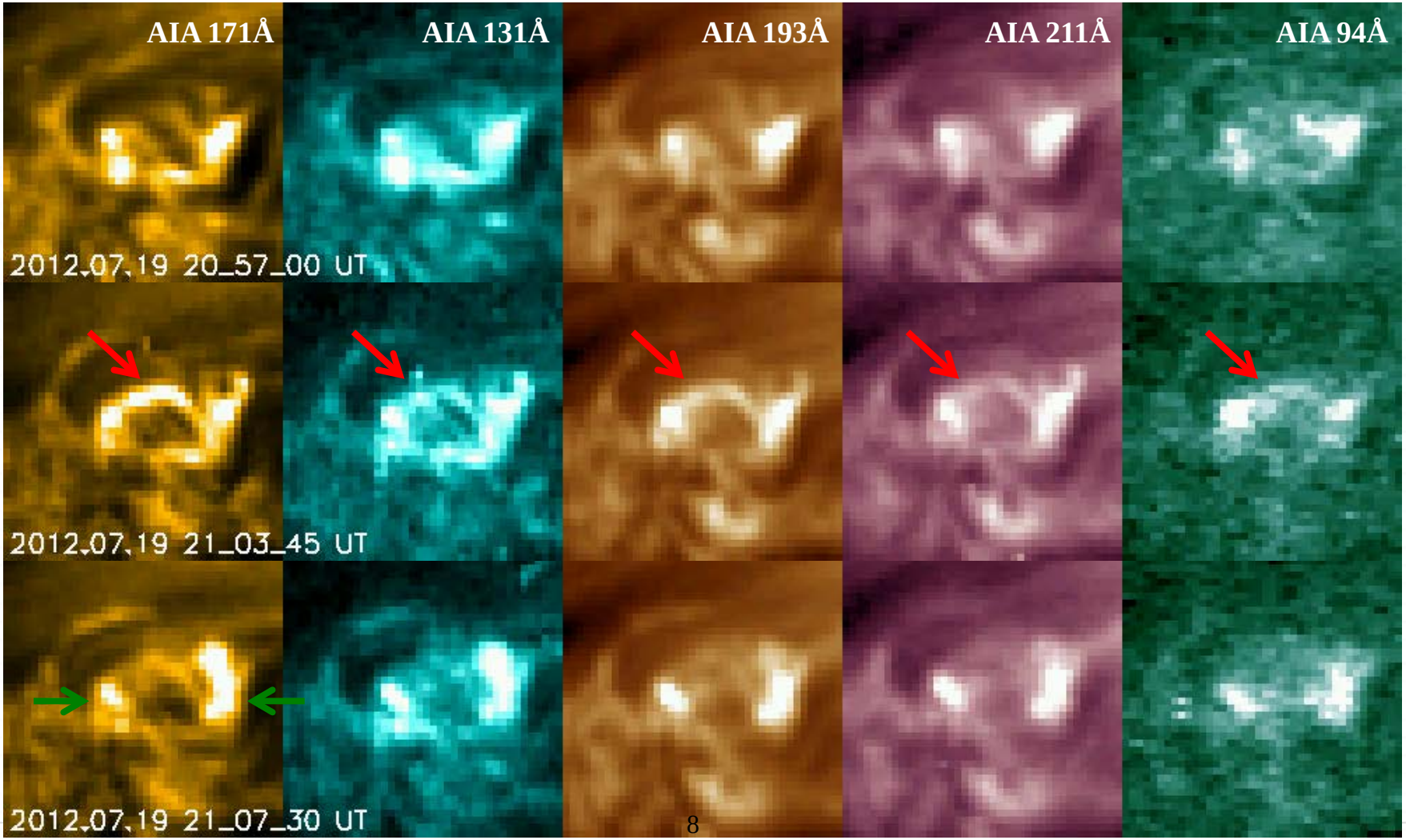


Results

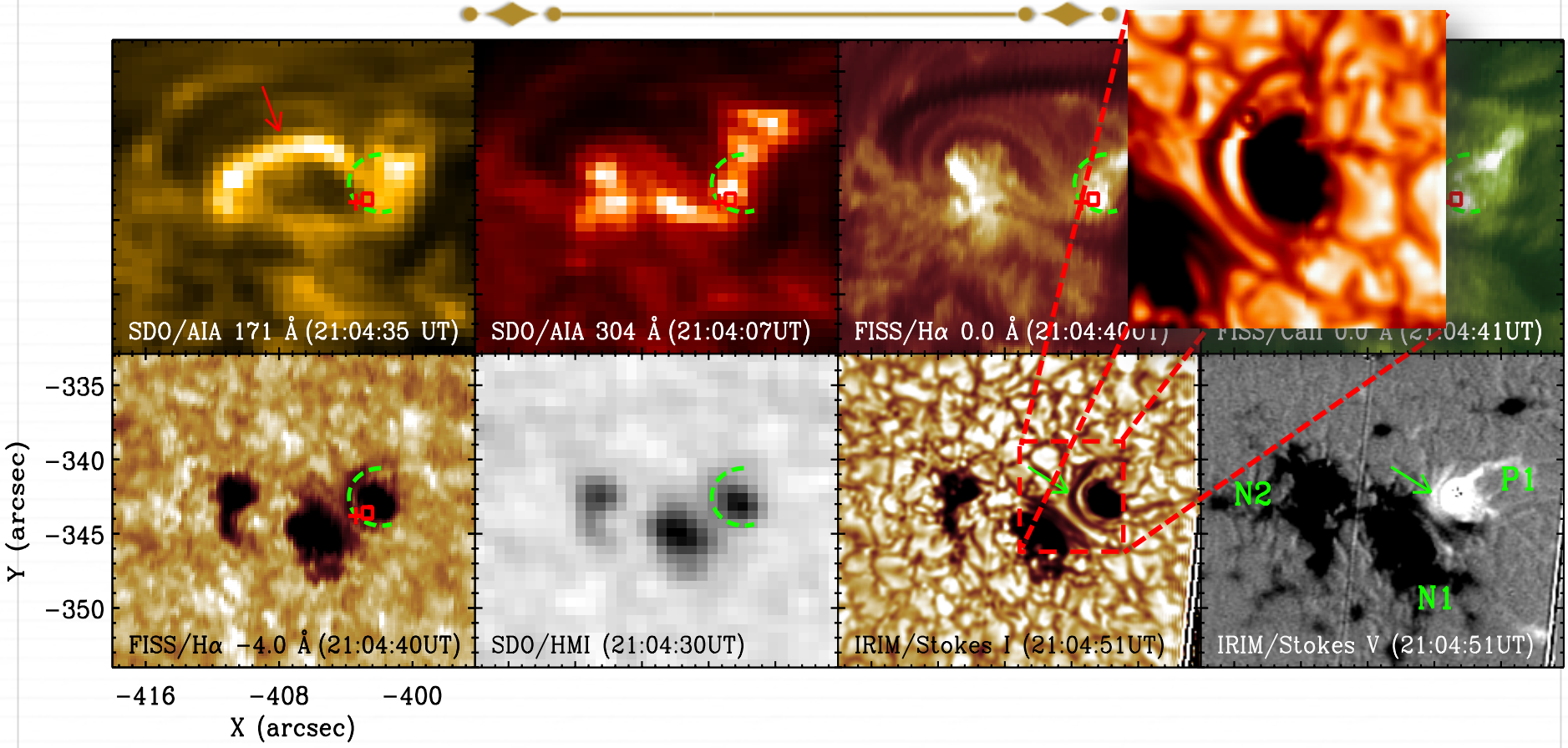


- a transient brightening in a small coronal loop (less than 10 Mm)
- reached a peak in two minutes

Results

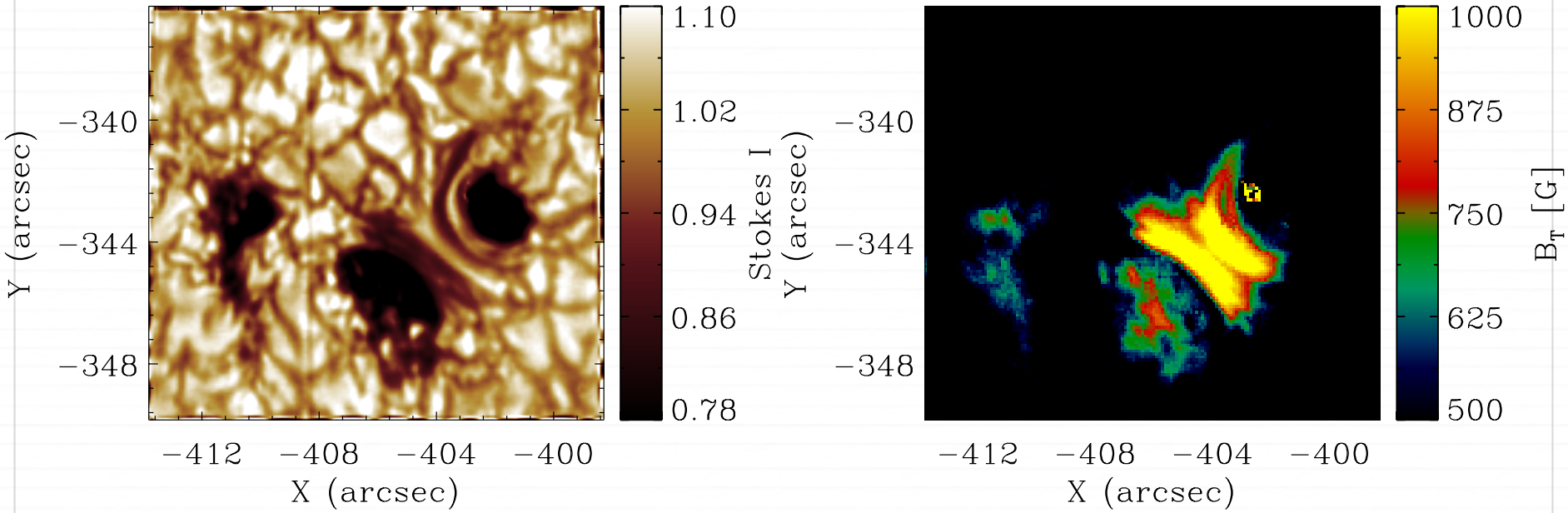

AIA 171Å
AIA 131Å
AIA 193Å
AIA 211Å
AIA 94Å
2012.07.19 20_57_00 UT
2012.07.19 21_03_45 UT
2012.07.19 21_07_30 UT

Results



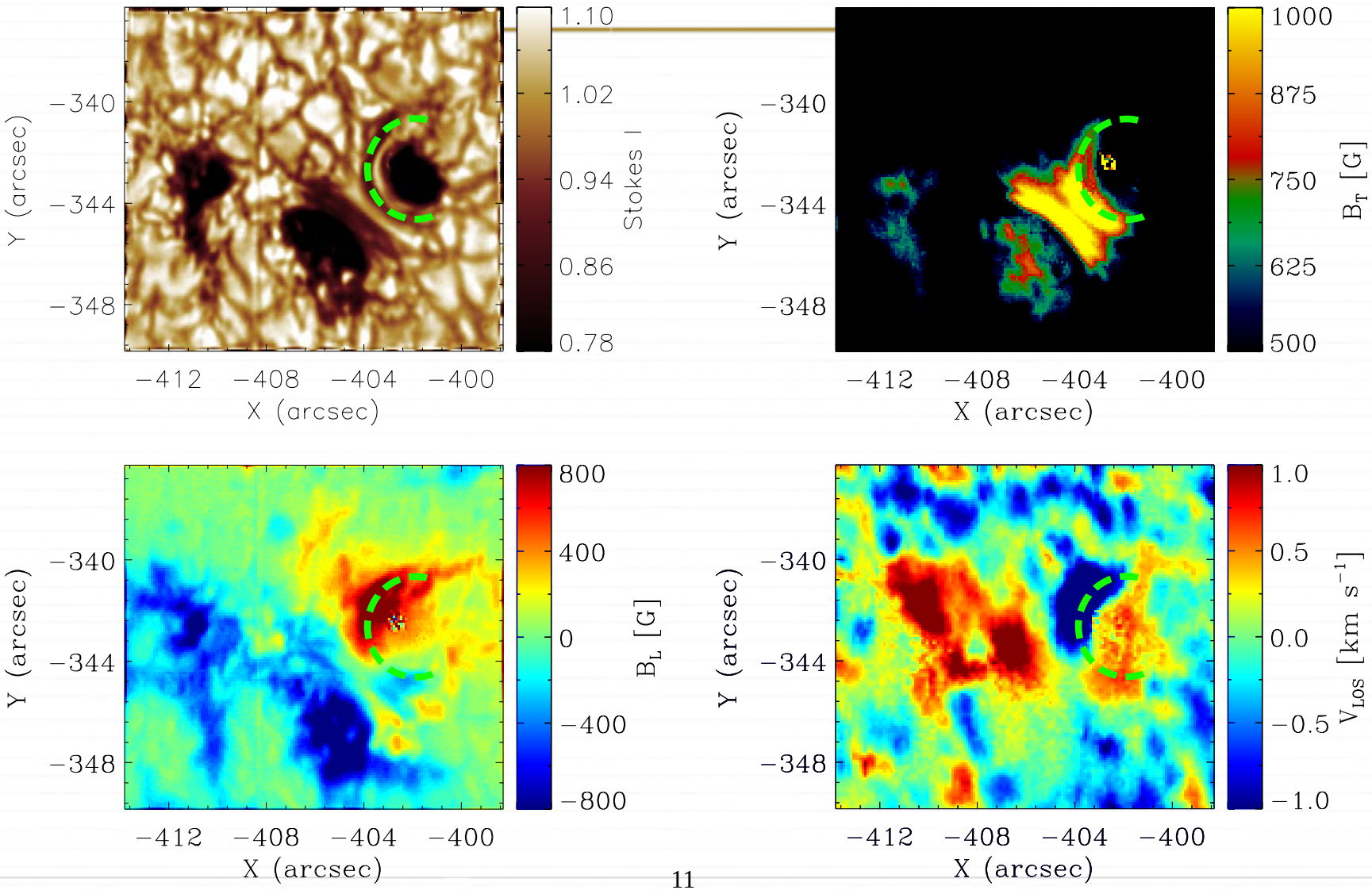
- highly sheared magnetic features – the negative sign of magnetic helicity
- a thin dark lane partially encircling the pore.

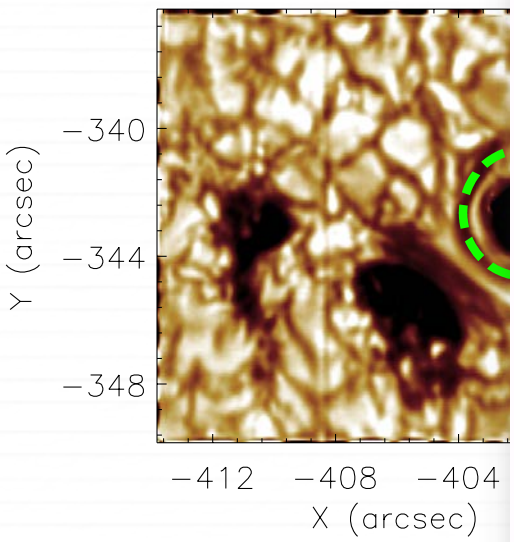
Results

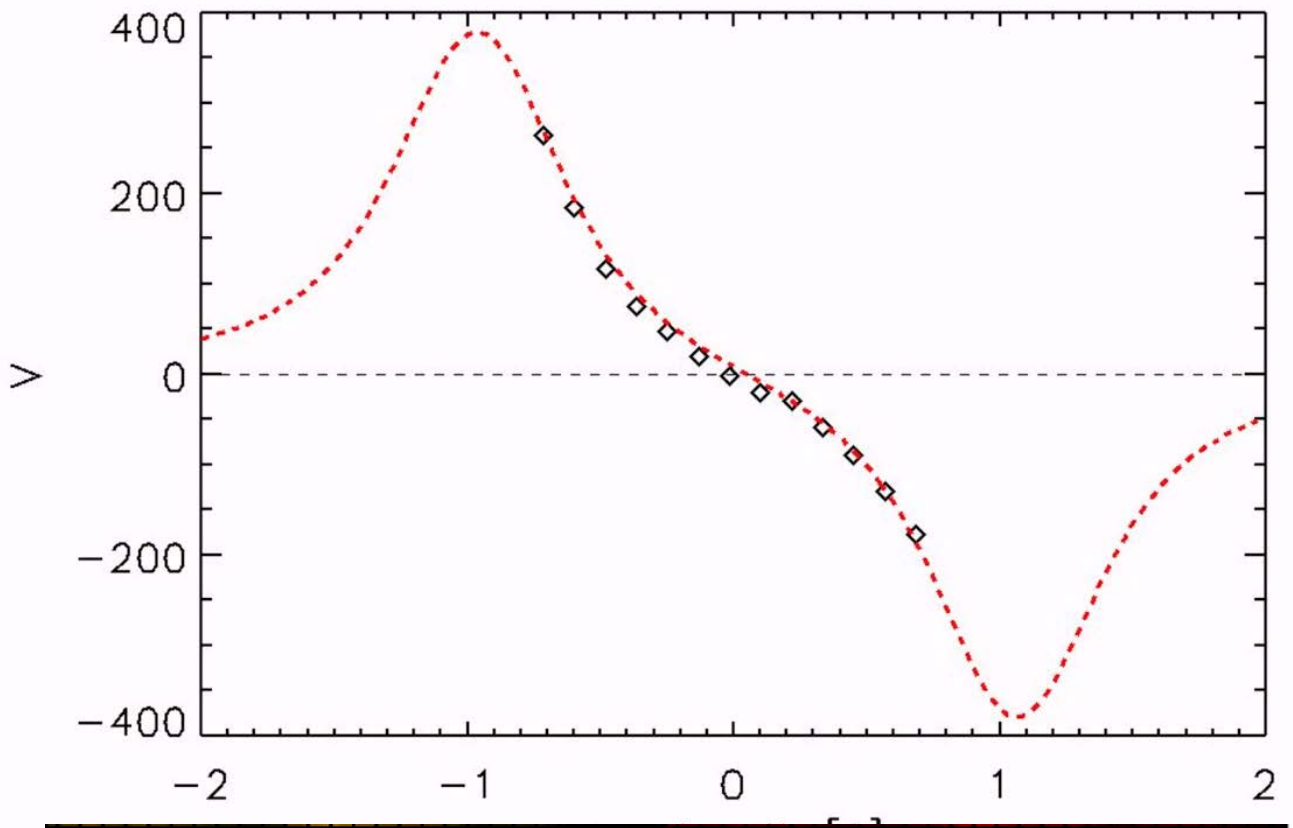


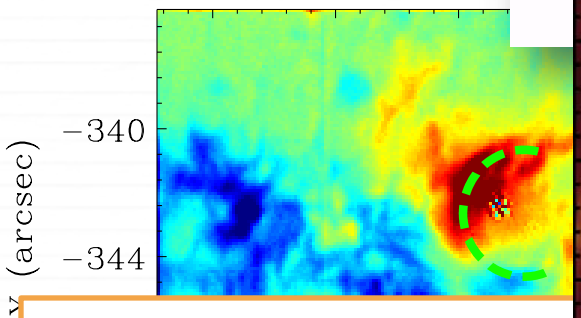
- the dark lane
  - length ~ 3700 km, width < 300 km, gap < 200 km
  - intense horizontal magnetic field (~ 1000 G)

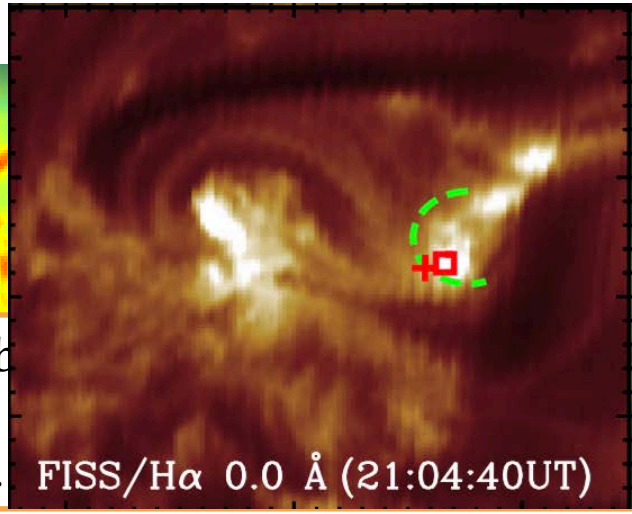
Results

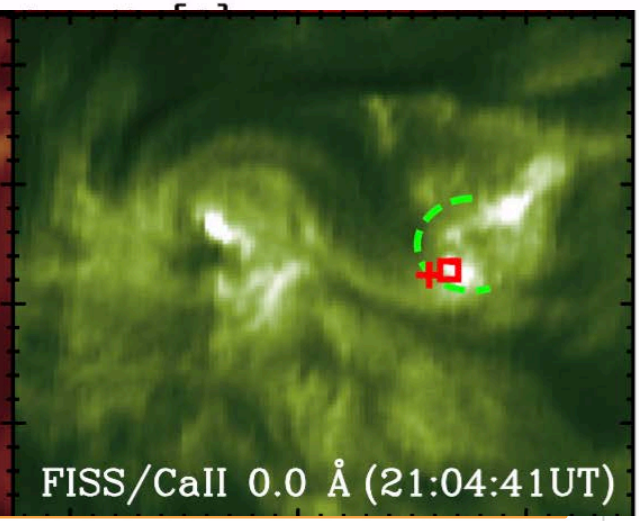

Y (arcsec)
−340
−344
−348
−412
−408
−404
−400
X (arcsec)
1.10
1.02
0.94
0.86
0.78
Stokes I
1000
875
750
625
500
B_T [G]
800
400
0
−400
−800
B_L [G]
1.0
0.5
0.0
−0.5
−1.0
V_{LOS} [km s^{-1}]









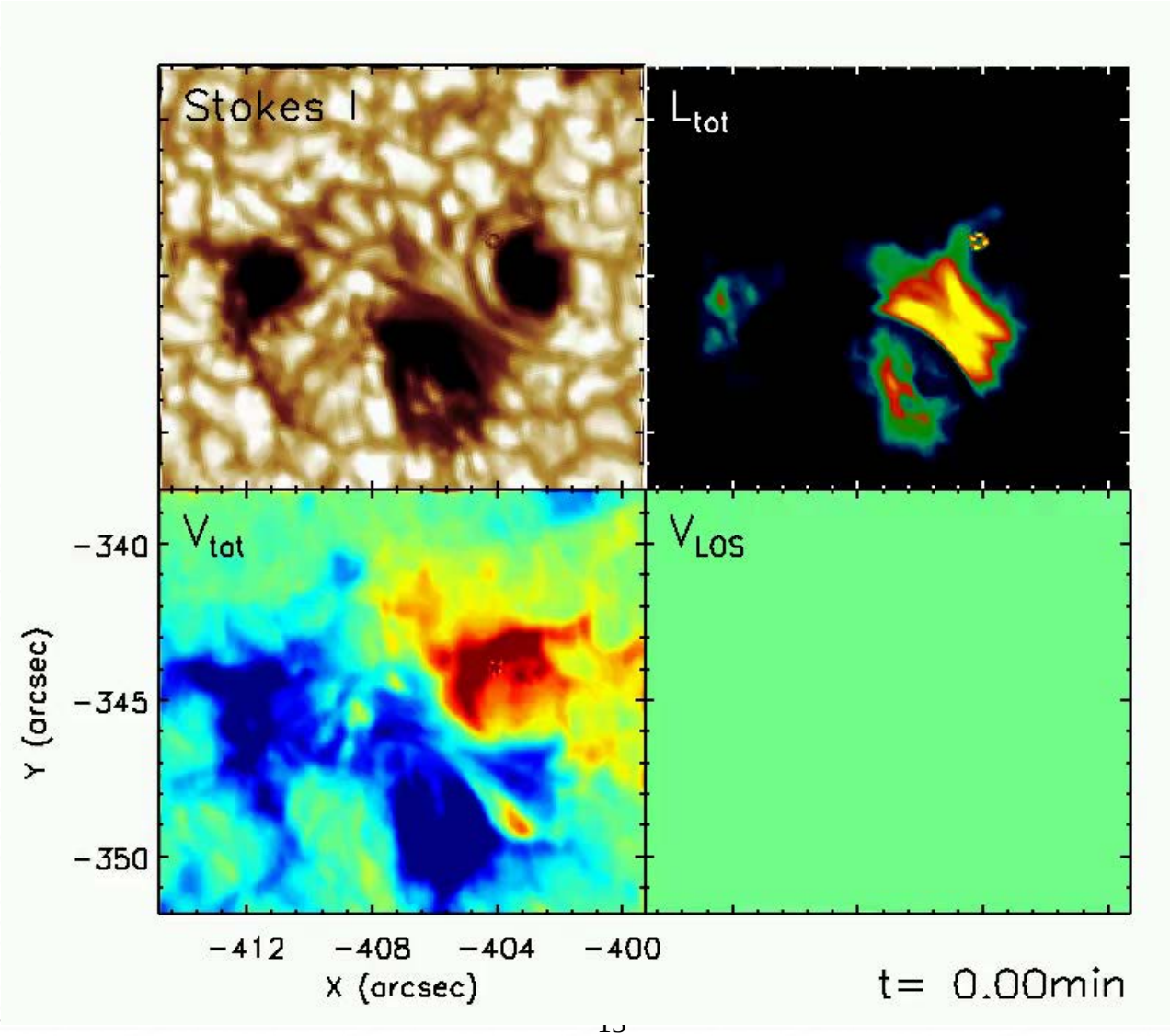


The gap is very narrow (ab
considered as a tangential
from the nanoflare theory.

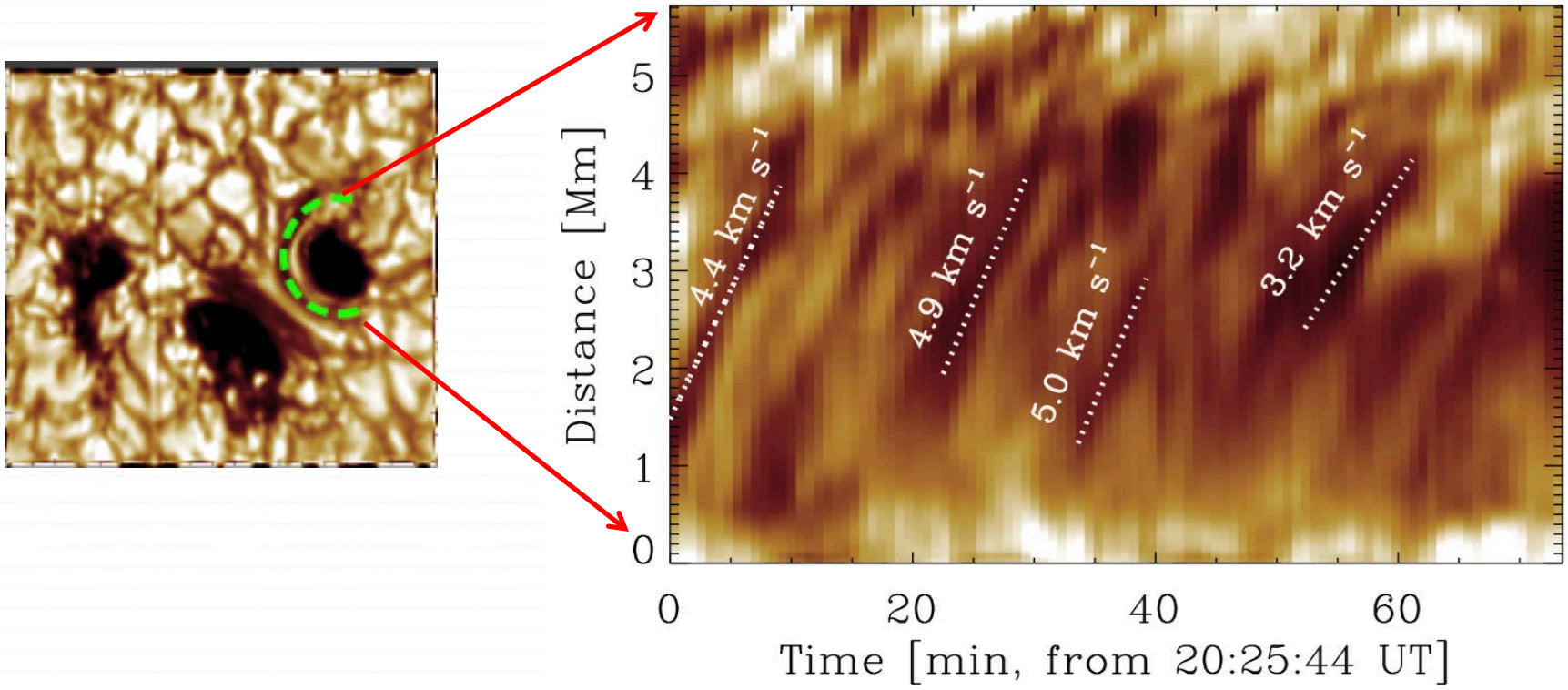
X (arcsec)

X (arcsec)

Results

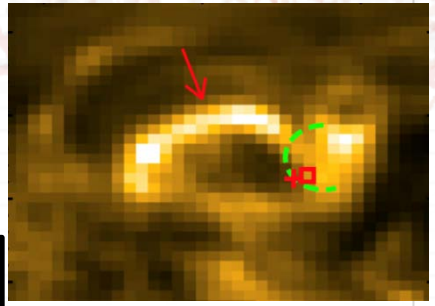

Stokes I
L_{tot}
V_{tot}
V_{LOS}
−340
−345
−350
Y (arcsec)
−412
−408
−404
−400
X (arcsec)
t= 0.00min

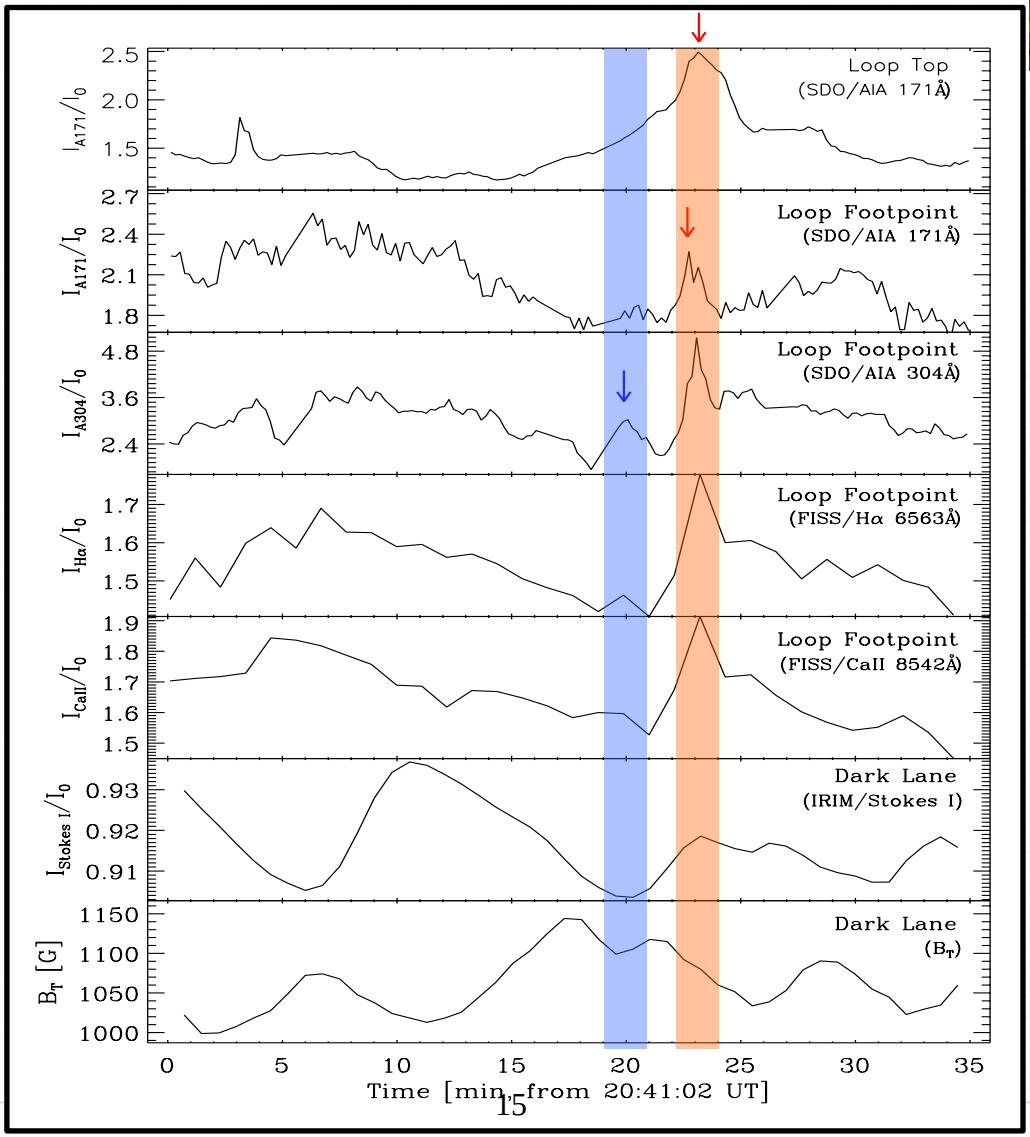
Results



- high-speed horizontal motion (5 km/s, time interval ~ 10-15 min)

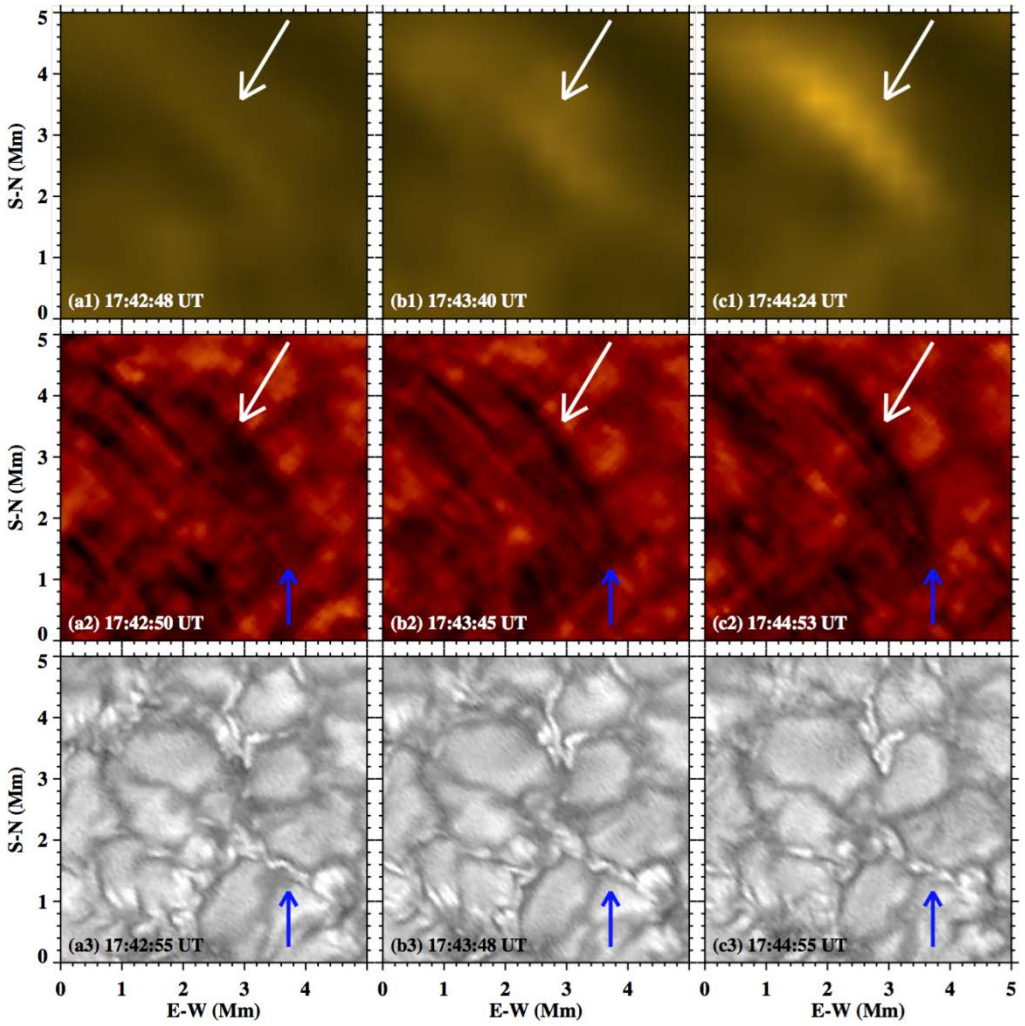
Results



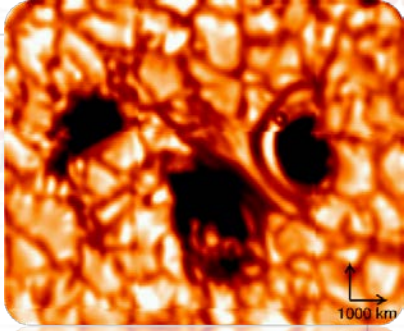

Loop Top
(SDO/AIA 171Å)
Loop Footpoint
(SDO/AIA 171Å)
Loop Footpoint
(SDO/AIA 304Å)
Loop Footpoint
(FISS/Hα 6563Å)
Loop Footpoint
(FISS/CaII 8542Å)
Dark Lane
(IRIM/Stokes I)
Dark Lane
(B_T)
I_A171/I_0
I_A304/I_0
I_Hα/I_0
I_CaII/I_0
I_Stokes I/I_0
B_T [G]
Time [min from 20:41:02 UT]

Summary and Conclusion

Ji et al. 2012, Zeng et al. 2013



Summary and Conclusion



- We detected an unprecedented fine-scale discontinuity of photospheric magnetic fields that is related to coronal loop heating.

- Our observational results support the nanoflare theory (Parker 1988)

  - the tangential discontinuity of magnetic field is crucial component for the heating.

- Differences between our results and the classical nanoflare theory.

  - the magnetic discontinuity is not detected in the coronal loop, but in the photosphere

  - small-scale magnetic reconnections may be occurring in the low atmosphere rather than in the corona loop.

  - we have not found the braiding of field lines by random motions in the photosphere.